ACADEMIC RESEARCH INSTRUMENTS:

EXPENDITURES 1993

NEEDS 1994

Surveys of Science Resources Series
Special Report
National Science Foundation
NSF 96-324

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EXECUTIVE SUMMARY

BACKGROUND

The National Survey of Academic Research Instruments and Instrumentation Needs (instrumentation survey) is a congressionally mandated program that collects data concerning scientific research instruments and the academic departments and facilities in which they are located. The survey covers a broad spectrum of science and engineering fields: agriculture, biology, computer science, environmental sciences, chemistry, physics/astronomy, and engineering.

The instrumentation survey is sponsored and conducted by the National Science Foundation (NSF), and is co-sponsored by the National Institutes of Health (NIH).

Data for this survey were collected from a panel of 79 institutions selected to represent the population of all academic institutions that each annually performs a minimum of $3 million in research and development (R&D). For the 1993 survey this population totaled 318 institutions, and accounted for more than 90 percent of the total performance of academic R&D in science and engineering in the United States.

EXPENDITURES FOR THE PURCHASE OF ACADEMIC SCIENTIFIC RESEARCH INSTRUMENTATION

Total Expenditures.—Total annual expenditures for the purchase of academic scientific research instrumentation were $1,203 million in 1993, an increase in current dollars of 6 percent over the amount spent in the last survey in 1988–89. In constant dollars,[1] however, total expenditures in 1993 were 10 percent below the level in 1988–89.

SOURCES OF FUNDS FOR THE PURCHASE OF NEW INSTRUMENTATION

Federal Sources.—In 1993, the Federal Government provided $624 million, or 52 percent of the $1,203 million total expenditures for academic research instruments. Three agencies contributed 70 percent of the total Federal contribution:

The National Science Foundation provided $213 million, or 18 percent of total expenditures during 1993. The National Institutes of Health provided $117 million, or 10 percent of the total. The Department of Defense contributed $106 million, or 9 percent of the total.

All other agencies combined contributed $186 million in 1993, an additional 15 percent of total expenditures.

Non-Federal Sources.—In 1993, non-Federal sources provided $580 million, or 48 percent of the total expenditures for academic research instruments. The largest single source of funds was the contribution from the academic institutions themselves, which provided $292 million, or 24 percent of the total. Funding from State grants or appropriations amounted to $102 million, or 8 percent of the total. Industry contributed $80 million, or 7 percent of the total. All other sources (including private, nonprofit foundations, gifts/donations, and bonds) contributed $105 million, or 9 percent.

EXPENDITURES FOR MAINTENANCE/REPAIR AND OPERATION

Aggregate expenditures for **maintenance/repair** in 1993 fell for the first time since the survey began in 1982. These expenditures comprise service contracts and field services, salaries of maintenance personnel, and other costs such as tools and supplies. These expenditures decreased from $289 million in 1988–89 to $234 million in 1993, a decline of 19 percent in current dollars. Expenditures for the

[1] Based on the GDP (gross domestic product) deflator and a base year of 1987

operation of existing instrumentation fell 22 percent between the two surveys, from $726 million in 1988–89 to $563 million in 1993.

Overall, expenses for the upkeep of the existing stock of instrumentation totaled 66 percent of the cost of purchasing new equipment. In other words, for every dollar spent in acquiring new instrumentation, an additional $0.66 was spent on maintaining and operating the existing stock.

ADEQUACY OF EXISTING RESEARCH INSTRUMENTATION

In 1993, slightly more than half of all respondents (56 percent) reported that there were subject matters in which their faculty investigators were unable to perform critical experiments because needed equipment was lacking. Although a majority of respondents still report this limiting condition, this represents a marked decrease in the percentage of respondents reporting a lack of equipment for critical experiments since the first survey in 1983–84, when 74 percent of the respondents reported such limitations.

Thus, there has been steady improvement in the availability of research instruments to academic researchers, but the continued lack of specific instruments is a significant limitation for the scientific community, where a majority of respondents in all fields but one reported an inability to perform critical experiments because of a lack of instruments.

Computer science was the only field in which less than a majority of respondents (44 percent) cited an inability of their faculty to perform critical experiments due to lack of suitable equipment.

NEED FOR NEW RESEARCH INSTRUMENTATION

Overall, 69 percent of respondents reported that their research instrumentation needs had increased in the two-year period since 1992.

Top priority needs by all respondents.— Department chairs and heads of facilities were asked to indicate the three pieces of equipment costing $20,000 or more that were most needed to bring their unit's[2] research equipment up to the full capabilities of their faculty. They were asked to prioritize these items and to estimate the purchase price of each.

If all three of the top priority items reported by each respondent could be purchased, the total estimated cost would be $2,048 million. Of this amount, $942 million, or 46 percent of the total, was the estimated cost of acquiring only the first-priority item.

Overall, 47 percent of respondents in all fields reported that the primary reason they needed the first-priority item was to "upgrade capabilities" for the unit, i.e., to perform experiments that they "cannot do now."

Needs by Respondents Reporting Current Inadequate Instrumentation.— Respondents were asked to rate their unit's instrumentation on a 5 point scale from excellent to poor. Forty-two percent of the respondents reported that the capability of their research instruments to enable the existing faculty to pursue their major research interests was "inadequate" or "poor." This group of respondents was then asked to estimate the cost to acquire sufficient research equipment that would fully support existing faculty.

This group estimated that it would cost $1,438 million to bring their research instrumentation to a point that would fully enable existing faculty to pursue their major research interests.

This amount was higher than the total of their top three priority needs. The 42 percent of respondents reporting inadequate instrumentation estimated that the purchase of their top three priority needs would cost $939 million. This represented 46 percent of the total of $2,048 million estimated by all respondents, nearly the same percentage as their proportion of total respondents.

[2] For this report, "unit" is used as a generic term that includes both departments and facilities. A department is an institutional unit that awards academic degrees; a facility is an institutional unit that does not award academic degrees. Either may have faculty assigned to it.

General Notes

Survey Background and Scope of This Report

The National Survey of Academic Research Instruments and Instrumentation Needs (instrumentation survey) is a congressionally mandated program that collects data concerning scientific research instruments and the academic units in which they are located for a broad spectrum of science and engineering fields. The survey is conducted by the National Science Foundation (NSF), and is co-sponsored by the National Institutes of Health (NIH).

This report analyzes overall instrumentation issues and trends in all the fields covered by the survey: agriculture, biology, chemistry, computer science, environmental sciences, physics/astronomy, and engineering.

A companion report published by NIH, *Academic Research Instruments and Instrumentation Needs in the Biological Sciences: 1994*, will give a more detailed analysis of the overall biological sciences field, and of seven major subfields of the biological sciences: biochemistry, cell biology/genetics, microbiology, pathology, pharmacology, physiology/biophysics, and other biological sciences.[3]

Background

During the late 1970s reports came before Congress suggesting that the capability of research instrumentation available to scientists and engineers at leading research universities was often inadequate to meet the needs of cutting-edge research. It was feared that this condition might seriously weaken the quality of the Nation's academic research capabilities. Desiring national data on this issue, Congress directed NSF to " . . . develop indices, correlates, or other suitable measures or indicators of the status of scientific instrumentation in the United States and of the current and projected needs for scientific and technological instrumentation" (Public Law 96-44, Section 7).

To fulfill this congressional directive, NSF, in conjunction with NIH, has conducted four cycles of the instrumentation survey. The surveys focused upon four main aspects of academic research instrumentation in departments and facilities. (For this report, a department is defined as an institutional entity that awards academic degrees; a facility is an institutional entity that does not award academic degrees. Either may have faculty assigned to it. For this report, "unit" is used as a generic term that includes both departments and facilities.) The four main topics are:

- expenditures for the purchase of research instruments and the sources of funds for those purchases;
- maintenance, repair, and operating costs connected with the stock of research instruments;
- amount, status, adequacy, and capability of the current stock of research instruments; and
- needs for upgraded or additional research instrumentation.

With slight changes of coverage, the survey has been collected from the same panel of institutions since 1983. This panel of 79 institutions was selected from, and represents, the population of all institutions that annually each perform a minimum of $3 million in research and development (R&D). In 1993, this population totaled 318 institutions.

Data Considerations

Context

Conducting a survey to quantify the current status and future needs for research instrumentation in a sector as varied as the American higher education system is a difficult task that requires the cooperation of many respondents. Questions about needs and assessments of the adequacy of current instrumentation must be asked at the micro-level, i.e.,

[3] This report will be made available over the World Wide Web. Check the NIH home page at http://www.nih.gov/ for more information.

at the departments and facilities where the research is originating. A complex sampling scheme was developed to minimize the reporting burden on academia.

This survey concentrates on the research-intensive institutions that annually perform more than $3 million in research and development. Therefore, the data on expenditures and needs by this group as a whole, as well as data on the median expenditures per unit, might tend to be larger than the responses that would have been obtained at less research-intensive institutions not canvassed by this particular survey.[4]

The set of questions used in the survey were devised to reflect the diverse needs of different science and engineering disciplines, so that the resulting national totals would give an accurate overall view of the status of research instrumentation needs[5] in academia. The survey questions were devised to obtain different nuances to the evaluation of the adequacy of current research instrumentation that arise from the highly individualized needs of different disciplines: for example, chemistry, physics/astronomy, and certain engineering and environmental sciences typically require large-scale instrumentation to carry out cutting-edge research. In general, the median expenditures, and median needs per unit, are larger in these disciplines than the per-unit expenditures in fields such as biology and agriculture, whose cutting-edge instrumentation is often less costly.

This survey was designed to report on the objective needs of the existing faculty from the perspective of the respondents, and was not intended to produce data for subjective, comparative analyses, such as whether there is a "right" amount of instrumentation needed by units of a certain size faculty. Similarly, the survey reports actual expenditures data such as the amount spent to purchase equipment, but does not report on the total allocation of resources, such as what proportion of total resources available to the unit was spent on instrumentation.

For a more complete discussion of the methodology of this series of surveys, and the changes in methodology made in cycle IV, see the technical notes in section C.

Presentation of Data

As would be expected from a survey fielded to a large cohort of respondents, tabulation of responses to the questionnaires yielded a great amount of data. To preserve the richness of the data, detailed tabulations were prepared that present the data by type of instrument and field of science and engineering. The report is organized to assist both the reader interested in the general overall policy issues, and the researcher wishing to obtain fine detail.

In general, the text will summarize the highlights of each set of data, and indicate the tables where additional detail can be found. The tables that are of most interest to the general reader, i.e., tables that contain trend and/or summary data, are included in the body of the text. Tables offering fine detail of data, that will be of interest primarily to a smaller subset of readers, are presented in appendix A.

The trend tables indicate that there were three years between the first three surveys (e.g., 1982–83, 1985–86) and a longer period between the 1988–89 and the 1993 survey. To relieve respondent burden, only the Department Questionnaire was fielded in 1992. The methodology was so different that trend tables in this report do not contain data for 1992. It is not clear at this time when the next instrumentation survey will be conducted.

[4] NSF and NIH have investigated several methods to broaden the coverage of the current survey. A pilot study of the biology departments at historically black colleges and universities (HBCUs) was conducted in 1995 and the results will be published in 1996. A feasibility study for adding less research-intensive schools, such as the departments at schools that were recipients of NIH's AREA grants, was conducted in late 1994. Results from these studies will be used in re-formatting future instrumentation surveys.

[5] An instrument was classified as "research" if it were used wholly or in part for research. Therefore, the need for dual-use instrumentation is included in the analysis in this report.

SECTION A.

ANNUAL EXPENDITURES FOR RESEARCH INSTRUMENTATION

TOTAL EXPENDITURES FOR THE PURCHASE OR ACQUISITION OF RESEARCH INSTRUMENTS

Context

During the first two cycles of this survey in 1982–83 and 1985–86, data were collected only for instruments (and their corresponding departments and facilities) with an original purchase price of $10,000 to $999,999. Beginning with the 1988–89 survey, coverage was expanded to include instruments with an original purchase price of $1 million or more. To maintain the richness of longitudinal data collected about the departments and facilities (units) having all instruments under $1 million, the trend tables in this report were developed so that the units are split between those units with all instruments under $1 million and those with at least one instrument over $1 million. **This reporting split was a methodological artifact, and does not imply any other meaning about the relative importance of the size of the units, nor can it be used to predict behavior of the different sized units. The size separation was done solely to facilitate presentation of the varied availability of data from the survey.** For economy of words, this report will refer to the units containing at least one instrument costing $1 million or more as "larger" units, and those with no instrument costing at least $1 million as "smaller" units.

The Question

Respondents were asked to give an estimate of "the total expenditures in this unit for the purchase/acquisition of scientific research equipment or equipment systems[6] *during the institution's 1993 fiscal year."*

Findings

Total annual expenditures for the purchase of academic scientific research instrumentation were $1,203 million in 1993, an increase in current dollars of 6 percent since the last survey in 1988–89 (table 1). However, this increase occurred primarily in the "smaller" units. Expenditures in these units increased 19 percent since the last survey, from $787 million in 1988–89 to $935 million in 1993.

Many of the larger units in the survey reported decreased expenditures. Overall, expenditures in these "larger" units decreased $83 million since the 1988–89 survey; the $268 million spent in 1993 was a 24-percent reduction from 1988–89. Decreases in the larger units were in three fields—engineering, biology, and computer sciences—but the bulk of the decline was in expenditures in computer science facilities; outlays in these units dropped from $183 million in 1988–89 to $62 million in 1993. (See the special computer science analysis on page 11 for a discussion of the changes in computer science facilities.)

In constant dollars,[7] total expenditures in 1993 were 10 percent below the level in 1988–89. The constant-dollar decline was experienced entirely by the larger units, where expenditures dropped 36 percent since the 1988–89 survey. During the same period the expenditures in the smaller units showed minimal upward change, with a 2-percent total increase in constant dollar outlays since 1988–89.

EXPENDITURES BY FIELD OF SCIENCE AND ENGINEERING

There were large variations in expenditures depending upon the field of science. Three fields of science experienced a decline in current dollar spending over the amount purchased in 1988–89: agriculture (a 5-percent decrease to $42 million), multidisciplinary fields (a 28-percent decrease to $39 million), and computer science (a 44-percent decrease to $127 million). Although this was the largest decline of any field reporting in the survey, *the decline occurred exclusively at central computer facilities, which experienced a 61-percent drop in expenditures between the two survey years. At the same time, departmental computer science expenditures increased by 50 percent since the 1988–89 survey* (table 1).

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[6] For this survey, a "system" is defined as an interrelated collection of items effectively comprising one single instrument.

[7] Constant dollars were derived by using the GDP deflator.

Table 1. Annual expenditures for the purchase of academic research instrumentation, by type of unit and field of science and engineering: 1982-83 to 1993

[Dollars in millions]

Type of unit and field of science and engineering	Survey year			
	1982-83	1985-86	1988-89	1993
Total, all units	--	--	$1,139	$1,203
Engineering	--	--	267	295
Chemistry	--	--	87	112
Physics/astronomy	--	--	139	211
Environmental sciences	--	--	64	94
Computer science	--	--	228	127
Academic departments	--	--	34	51
Computer facilities	--	--	193	76
Agricultural sciences	--	--	44	42
Biological sciences	--	--	256	283
Other, multidisciplinary	--	--	54	39
Total, units with all instruments costing less than $1,000,000	$398	$669	787	935
Engineering	93	173	200	260
Chemistry	39	76	83	95
Physics/astronomy	52	83	72	110
Environmental sciences	30	51	54	63
Computer science	16	47	41	58
Academic departments	14	39	30	44
Computer facilities	2	8	11	14
Agricultural sciences	27	32	44	41
Biological sciences	130	185	247	279
Other, multidisciplinary	10	21	46	31
Total, units with an instrument costing $1,000,000 or more	--	--	351	268
Engineering	--	--	67	35
Chemistry	--	--	4	18
Physics/astronomy	--	--	66	102
Environmental sciences	--	--	10	31
Computer science	--	--	187	69
Academic departments	--	--	4	7
Computer facilities	--	--	183	62
Agricultural sciences	--	--	0	-
Biological sciences	--	--	10	4
Other, multidisciplinary	--	--	8	8

NOTES: This table, which includes data for all four survey cycles, is presented in a three-part format to reflect the changing coverage of instruments in the survey.

In 1982-83 and 1985-86 data were collected only for instruments (and their corresponding units) with an original purchase price of $10,000-$999,999.

In 1988-89 and 1993 coverage was expanded to include instruments with an original purchase price of $1,000,000 or more.

In 1993, the minimum purchase price of an in-scope instrument was changed from $10,000 to $20,000.

For consistency, data from the 1982-83, 1985-86, and 1988-89 surveys were standardized using the same minimum purchase price criterion of $20,000 in constant 1993 dollars, based on the GDP implicit price deflator. The $1,000,000 criterion was also standardized in constant 1993 dollars.

Because of rounding, details may not add to totals.

KEY: - = less than $500,000
-- = data not collected in that survey year

SOURCE: National Science Foundation/SRS, Survey of Academic Research Instruments and Instrumentation Needs: 1993

The engineering fields had the largest total expenditures for research equipment in 1993, with expenditures of $295 million, up from $267 million in 1988–89. Although this was an increase of 10 percent in current dollars, measured on a constant dollar basis, the expenditures were 7 percent less than those reported in the last survey in 1988–89. Expenditures in the biological sciences were the second highest for any field in 1993, $283 million, up from $256 million in 1988–89. This was an 11-percent increase; however, measured in constant dollars, it represented a decrease of 3 percent.

Total expenditures in physics/astronomy were the third highest, $211 million in 1993. The increase of $72 million since the last survey in 1988–89 was the largest absolute increase in any field, and the corresponding 52-percent increase was also the largest percentage increase of any field. (In constant dollars, the percentage increase was 28 percent over the expenditures in 1988–89.) Physics/astronomy is one of the few fields in which the expenditures of the larger units ($102 million in 1993) and the smaller units ($110 million) are fairly even. (In the majority of other fields, more money is spent in aggregate by the smaller units.) Units in physics/astronomy also experienced a similar percentage increase over the previous survey (53 percent and 55 percent, respectively). It is interesting to note that the large current-dollar increase by the smaller units in physics/astronomy between 1988–89 and 1993 follows an uneven pattern of spending reported in earlier surveys. There was a 60-percent increase in expenditures between 1982–83 and 1985–86 (from $52 million to 83 million), followed by a 13-percent decrease in the next survey in 1988–89 ($72 million).

Instrument expenditures in the environmental sciences[8] also rose considerably (47 percent) from $64 million in 1988–89 to $94 million in 1993. Two-thirds of the increase was in the larger units, which experienced a tripling in expenditures (a $21 million increase, from $10 million in 1988–89 to $31 million in 1993). The smaller units experienced a 17-percent increase, from $54 million to $63 million.

[8] The term “environmental sciences” used here includes the fields of earth sciences, atmospheric sciences, oceanography, and other environmental sciences not elsewhere classified.

MEDIAN EXPENDITURES FOR THE PURCHASE OF RESEARCH INSTRUMENTATION

Data Considerations

Part of the increase in total expenditures reported in each survey cycle is due to an increase in the number of units represented by the institutions in the sample, due primarily to two factors:

1. In each time period that the survey has been collected there has been a gradual increase in the number of *institutions* that perform over $3 million in R&D; therefore the survey respondents in each succeeding cycle represent more institutions.
2. The institutions sampled in this survey are generally large, dynamic, growing entities. There is typically a higher level of activity between each cycle of the instrumentation survey, and often the total number of *departments and facilities* at these institutions increases as well. As the number of units increases, the total expenditures at the institution also tends to increase.

Using the measure of median expenditures per unit allows an analysis of the change in expenditures that is independent of the increase in the total number of units. (Since there may be significant variation in the values for many variables collected in this survey, the median was chosen because it is not significantly affected by extreme values.)

Findings

The median expenditure per unit for the purchase of equipment in all fields increased from $166,000 in 1988–89 to $176,000 in 1993 (table 2). Not all disciplines participated in this increase. Median expenditures per unit for agricultural sciences, for example, dropped from $130,000 in 1988–89 to $90,000 in 1993, while median outlays per unit for engineering decreased by a smaller amount, from $162,000 to $154,000. The largest decrease per unit occurred in median expenditures for computer science, which decreased from a median of $490,000 in 1988–89 to $200,000 in 1993. Median

Table 2. Median annual expenditures per unit for the purchase of academic research instruments, by type of unit and field of science and engineering: 1982-83 to 1993

[Dollars in thousands]

Type of unit and field of science and engineering	Survey year			
	1982-83	1985-86	1988-89	1993
Total, all units	--	--	$166	$176
Engineering	--	--	162	154
Chemistry	--	--	449	600
Physics/astronomy	--	--	309	400
Environmental sciences	--	--	101	154
Computer science	--	--	490	200
Academic departments	--	--	200	300
Computer facilities	--	--	642	175
Agricultural sciences	--	--	130	90
Biological sciences	--	--	150	153
Other, multidisciplinary	--	--	102	97
Total, units with all instruments costing less than $1,000,000	$84	$154	150	154
Engineering	82	184	150	150
Chemistry	250	346	431	550
Physics/astronomy	217	250	270	302
Environmental sciences	75	126	100	151
Computer science	160	383	200	177
Academic departments	155	383	197	315
Computer facilities	S	S	467	105
Agricultural sciences	56	100	130	90
Biological sciences	79	141	150	151
Other, multidisciplinary	68	78	102	90
Total, units with an instrument costing $1,000,000 or more	--	--	500	525
Engineering	--	--	408	529
Chemistry	--	--	S	S
Physics/astronomy	--	--	498	621
Environmental sciences	--	--	103	658
Computer science	--	--	782	252
Academic departments	--	--	S	S
Computer facilities	--	--	773	300
Agricultural sciences	--	--	S	S
Biological sciences	--	--	S	S
Other, multidisciplinary	--	--	S	S

NOTES: This table, which includes data for all four survey cycles, is presented in a three-part format to reflect the changing coverage of instruments in the survey.

In 1982-83 and 1985-86 data were collected only for instruments (and their corresponding units) with an original purchase price of $10,000-$999,999.

In 1988-89 and 1993 coverage was expanded to include instruments with an original purchase price of $1,000,000 or more.

In 1993, the minimum purchase price of an in-scope instrument was changed from $10,000 to $20,000.

For consistency, data from the 1982-83, 1985-86, and 1988-89 surveys were standardized using the same minimum purchase price criterion of $20,000 in constant 1993 dollars, based on the GDP implicit price deflator. The $1,000,000 criterion was also standardized in constant 1993 dollars.

Because of rounding, details may not add to totals.

KEY: S = fewer than 10 cases for analysis
-- = data not collected in that survey year

SOURCE: National Science Foundation/SRS, Survey of Academic Research Instruments and Instrumentation Needs: 1993

expenditures track the direction of total expenditures; the computer science decline was entirely in computer facilities, which experienced a 73-percent decline in median expenditures.

Median expenditures per unit in the other sciences increased during the period between the two surveys, but at differing rates. Chemistry, for example, had median expenditures per unit rise from $449,000 to $600,000, and physics/astronomy median expenditures per unit rose from $309,000 to $400,000. During the same time the biology median expenditure per unit rose only slightly, from $150,000 to $153,000.

SOURCES OF FUNDING FOR THE PURCHASE OF RESEARCH INSTRUMENTATION

The Question

Respondents were asked to estimate the "proportion of total expenditures for equipment in FY 1993 from each of the following sources: Federal (National Science Foundation; National Institutes of Health; Department of Defense; Department of Energy; and other Federal sources) and non-Federal (institution or unit funds; State grant or appropriation; industry; and other sources including private, nonprofit foundations, gifts/donations, and bonds).

Findings

Federal sources.—In 1993, the Federal Government provided $624 million, or 52 percent of the $1,203 million in total expenditures for academic research instruments (table 3). Funds generally came as part of a grant or contract for the conduct of research, or through special instrumentation programs set up by the Federal Government. The four agencies mentioned above contributed 84 percent of the total Federal contribution.

The National Science Foundation was the largest Federal source for research instrumentation funds in 1993, providing $213 million, or 18 percent of the total. The National Institutes of Health was the second largest Federal source, providing $117 million, or 10 percent. The Department of Defense was the third largest Federal source; providing $106 million, or 9 percent. The Department of Energy contributed $87 million, or 7 percent of the total.

All other agencies combined contributed $99 million, or 8 percent of the total expenditures.

Non-Federal Sources.—In 1993, non-Federal sources provided $580 million, or 48 percent of the total expenditures for academic research instruments (table 3). The largest single source of funds was the academic institutions themselves, which provided $292 million, or 24 percent of the total.[9] Funding from State grants or appropriations amounted to $102 million, or 8 percent of the total. Industry contributed $80 million, or 7 percent of the total. All other sources (including private, nonprofit foundations, gifts/donations, and bonds) totaled $105 million, or 9 percent of the total. (Bonds are a "source" of income only in a limited time sense, as the institutions in future years must pay back the borrowed money and accompanying interest payments from their other sources of income.)

EXPENDITURES FOR MAINTENANCE/REPAIR AND OPERATION OF EXISTING INSTRUMENTS

Context

Expenditures to maintain and operate the existing stock of scientific research instrumentation are an important additional cost that must be factored into the total research budget decisions by the head of every unit. The chairs of departments and facilities must choose among alternatives for spending, with research money being allocated at a minimum among personnel expenses; instrumentation purchases; and maintenance, repair, and operation of existing instrumentation.

[9] Institutional funds generally come from one of four sources: indirect cost recovery from awards from the Federal Government and other sources; State operating appropriations from general revenues; student tuition; and unrestricted gifts and income (e.g., endowments).

Table 3. Expenditures for the purchase of academic research instruments, by source of funds: 1993

[Dollars in millions]

Source of funds	Total
Total	$1,203
Federal, total	624
National Science Foundation	213
National Institutes of Health	117
Department of Defense	106
Department of Energy	87
Other Federal sources	99
Non-Federal, total	580
Institution funds	292
State grant or appropriation	102
Industry	80
Other non-Federal sources[1]	105

[1] Includes private, nonprofit foundations, gifts/ donations, and bonds.

NOTE: Because of rounding, details may not add to totals.

SOURCE: National Science Foundation/SRS, Survey of Academic Research Instruments and Instrumentation Needs: 1993

The instrumentation survey measured the amount of total maintenance/repair and operation expenses in comparison with the amount that was spent on purchasing new instrumentation, and reported the perception of the unit heads of the quality of assets available to them to maintain, repair, and operate their existing stock of instrumentation. To reduce respondent burden, the survey did not ask for information concerning the sources of funding for the costs incurred for maintenance/repair and operation.

The Questions

Respondents were asked to give the "FY 1993 expenditures for maintenance/repair and for operation of scientific research equipment in this unit. (Do not include fringe benefits or overhead costs.)"

In addition, given five-point rating scales ranging from excellent (1) to poor (5), they were also asked to assess the maintenance/repair of the research equipment in the unit, and the availability of resources in the unit to operate current equipment.

Maintenance/Repair of Existing Research Instrumentation

Findings

Expenditures.—Aggregate expenditures for maintenance/repair in 1993 fell for the first time since survey data collection began in 1982. Expenditures decreased from $289 million in 1988–89 to $234 million in 1993, a decline of 19 percent (table 4).

Maintenance/repair expenditures comprise service contracts and field services, salaries of maintenance personnel, and other costs such as tools and supplies. Expenditures fell at a much faster rate for the larger units (a decrease of 38 percent) than for the smaller units (6 percent) (table A-1). By size of unit, the bulk of the decline in the larger units (as would be expected) was in the computer science facilities.[10] Presumably, with fewer units in existence for the conduct of research, the aggregate expenses to maintain the research instrumentation also decreased.

[10] Unpublished NSF data.

The largest decrease by field was also in computer science facilities, where expenditures dropped from $85 million to $33 million. Agricultural sciences also experienced a large percentage decrease in maintenance/repair (36 percent), with outlays dropping from $11 million to $7 million.

Assessment of resources for maintenance/ repair.—Almost three-quarters of the respondents rated the maintenance/repair of their instruments as excellent to adequate. Most satisfied were the respondents from computer science facilities; 97 percent rated their maintenance/repair as excellent. At the other end of the scale, 40 percent of environmental science respondents and 39 percent of chemistry respondents rated maintenance/repair as inadequate to poor (table A-2).

Operation of Existing Research Instrumentation

Findings

Expenditures.—Expenditures for the operation of existing instrumentation fell 22 percent between the two surveys, from $726 million in 1988–89 to $563 million in 1993 (table A-3). Detail collected in the 1988–89 survey indicated that approximately 75 percent of total operation costs was used to pay the salaries of operators.[11]

Assessment of available resources for operation.—The majority of respondents (58 percent) were fairly satisfied with the resources available to them to operate their instrumentation, although the scores here were not as high as the satisfaction scores with maintenance/repair (see earlier discussion). Forty-seven percent of the respondents rated the resources as adequate, and 11 percent rated them as very good to excellent (table A-4).

[11] Data on expenditures for operation of equipment were first collected in the 1988–89 survey, and a breakdown by type of expenditure was included in the questionnaire. Comments from that survey's respondents indicated that it was exceedingly difficult to report a breakdown of operation expenditures by type; consequently, that level of detail was eliminated in the 1993 survey in an effort to reduce respondent burden.

Table 4. Expenditures for maintenance/repair and operation of stock of existing academic research instruments, by field of science and engineering: 1988-89 and 1993

[Dollars in millions]

Field of science and engineering	Total maintenance/repair/ operation		Type of cost			
			Maintenance/repair [1]		Operation [2]	
	1988-89	1993	1988-89	1993	1988-89	1993
Total	$1,014	$797	$289	$234	$726	$563
Engineering	138	157	42	58	97	99
Chemistry	42	46	18	13	24	32
Physics/astronomy	120	95	28	22	92	73
Environmental sciences	73	87	22	23	52	64
Computer science	348	163	99	47	248	116
Academic departments	28	29	15	14	13	15
Computer facilities	320	133	85	33	235	101
Agricultural sciences	53	26	11	7	42	19
Biological sciences	197	192	58	55	138	137
Other, multidisciplinary	43	31	10	7	33	24

[1] Maintenance/repair costs include maintenance agreements, service contract costs, salaries of department- or institution-provided maintenance/repair personnel, and cost of supplies, instruments, and facilities for servicing research instruments.

[2] Operating costs include salaries for technicians or other personnel paid to operate research instruments, and costs of supplies and materials used in operating the instruments.

NOTES: In 1993, the minimum purchase price of an in-scope instrument was changed from $10,000 to $20,000. For consistency, data from the 1988-89 survey were standardized using the same minimum purchase price criterion of $20,000 in constant 1993 dollars, based on the GDP implicit price deflator.

Because of rounding, details may not add to totals.

SOURCE: National Science Foundation/SRS, Survey of Academic Research Instruments and Instrumentation Needs: 1993

However, 42 percent of respondents from these research-intensive institutions rated the resources available for operation as less than adequate (34 percent) or poor (8 percent). Fifty-nine percent of the agriculture respondents rated the resources as inadequate to poor, the highest percentage of all the surveyed fields (table A-4). These same agricultural units experienced a 55-percent decrease in operation expenditures since the last survey, from $42 million in 1988–89 to $19 million in 1993 (table 4).

Fifty-three percent of the environmental sciences respondents and 50 percent of the chemistry respondents were dissatisfied with the availability of resources to operate equipment (table A-4), even though both of these fields experienced increases in the outlays for operation of equipment between the two surveys (from $24 million to $32 million for chemistry, and from $52 million to $64 million for environmental sciences) (table 4).

Budgetary considerations for maintenance/repair and operation.— Notwithstanding the reduced expenditures in 1993, outlays for maintenance/repair and operation were a considerable expense for the respondents. Overall, expenses for the upkeep and operation of the existing stock of instrumentation amounted to 66 percent of the cost allocated to purchasing new equipment in 1993. In other words, for every dollar spent on new purchases, an additional $0.66 was spent on maintenance/repair and operation of the existing stock (table 5).

These proportional expenditures varied by discipline, with computer science spending the highest proportion: For every dollar spent on new purchases, $1.28 was spent on the maintenance/repair and operation of the existing stock.

Within the field of computer science, the facilities had the highest proportion of these expenses of any field of science surveyed. For *maintenance/repair,* facilities spent $0.43 for every dollar spent on new purchases. This is not surprising, since the complexity of the large mainframe instrumentation makes it imperative to budget for service contracts and/or specially trained personnel to maintain the systems. Proportional expenditures for *operation* in computer facilities were also the highest for any field ($1.33 for every dollar of the cost of new purchases) as many of the mainframes and supercomputers cannot be utilized without the services of highly experienced operators.

Similarly, environmental sciences also had a very high proportion of operating expenses ($0.68 for every dollar spent on new purchases). Again, the research instrumentation often necessary in these disciplines—such as research vessels and electron microscopes—often requires the services of highly trained technicians and other specialized personnel.

Table 5. Expenditures for maintenance/repair and operation of stock of existing academic research instruments as a percent of expenditures for purchase of additional academic research instruments, by field of science and engineering: 1993

[Percent]

Field of science and engineering	Total maintenance/ repair/ operation	Type of cost	
		Maintenance/ repair [1]	Operation [2]
Total	66%	19%	47%
Engineering	53	20	33
Chemistry	41	12	29
Physics/astronomy	45	10	34
Environmental sciences	92	25	68
Computer science	128	37	91
Academic departments	57	27	30
Computer facilities	176	43	133
Agricultural sciences	62	17	45
Biological sciences	68	19	48
Other, multidisciplinary	80	19	61

1 Maintenance/repair costs include maintenance agreements, service contract costs, salaries of department- or institution-provided maintenance/repair personnel, and cost of supplies, instruments, and facilities for servicing research instruments.

2 Operating costs include salaries for technicians or other personnel paid to operate research instruments, and costs of supplies and materials used in operating the instruments.

SOURCE: National Science Foundation/SRS, Survey of Academic Research Instruments and Instrumentation Needs: 1993

SECTION B.

SPECIAL ANALYSIS OF EXPENDITURES DATA

CHANGES SINCE 1988–89 IN COMPUTER SCIENCE INSTRUMENTATION EXPENDITURES

Total expenditures for research instrumentation in computer science varied considerably by the type of unit, reflecting in large part the changing role of central computer facilities in science and engineering research. Expenditures at central computer facilities dropped 61 percent since the last survey in 1988–89 (from $193 million to $76 million), while expenditures in computer science departments increased 50 percent to $51 million (table 1).

There is of course continuing demand for powerful large computers and for supercomputers, and their usage has been increasingly shared among researchers in the academic community due to the rapid increase in networking access to off-site research computers via electronic connections. Since the last survey in 1988–89, however, the phenomenal growth in the computational capabilities of personal computers and workstations, coupled with their continued decrease in price, has changed the purchase pattern for computers being used for research in all disciplines. The emphasis on many campuses is increasingly away from the purchase of large mainframe computers housed in central facilities, and toward the purchase of smaller, very powerful computers that can be located in the laboratories and offices of the researchers themselves.

Thus, while many of the largest computers and the supercomputers are still utilized heavily, and their aggregate cost is great, new purchases are increasingly the less expensive but very powerful computers to be housed in the researchers' own laboratories, many of which have networking capability for off-site research and collaboration. As a result, new research instrument purchases at central computer facilities were still very costly, but had dropped to 60 percent of computer science expenditures in 1993, down from 85 percent in 1988–89.

Other data from the survey corroborated this change. The number of computer facilities reported in the 1993 survey was lower than the number reported in the 1988–89 survey; followup calls were made to ascertain the reasons for the decline. On many campuses, there had been a change in the academic mission of many of the mainframe computers housed in central computer facilities: Many of the mainframes utilized as research instruments in the 1988–89 survey were reported in the 1993 survey as being used primarily for administrative purposes instead. As a result, any continued expenditures at these computer facilities were not considered to be research expenditures, and consequently were not reflected in this survey.

Although the overall importance of computer instrumentation in research has continued to increase, the reporting of expenditures for computer research instruments may have moved from being expenditures for the discipline of computer science to being expenditures in the originating disciplines.

This change is illustrated by the answers to the survey question that asked respondents to list the research instrument considered the top priority item of need in their units. Twenty-eight percent of *all* respondents listed computers as *their top priority item of need*. As would be expected, 99 percent of respondents from computer science listed a computer as the top priority item, but 35 percent of respondents from both the environmental sciences and engineering also listed a computer as *their top priority item* (table A-10).

Research instrumentation needs at the remaining computer science facilities used for research are of course quite large in the aggregate, reflecting the very high cost per-item for instruments in these units. The median cost for a top priority computer for the computer science facilities ($200,000) is far greater than the cost of the top-priority computer for any other discipline (table A-10).

INSTRUMENTATION EXPENDITURES PER FACULTY MEMBER

Context

To make well-informed policy decisions about research instrumentation funding it is necessary to know the extent of total expenditures by the various fields. However, some other normalizing procedure must also be used to relate total expenditures data to the actual experiences in each unit. The responding institutions in this survey represent some of the very largest academic research institutions, and their departments and facilities are often larger than corresponding units in other institutions. Larger units tend to have more faculty and therefore more research activity, which increases instrumentation expenditures based on size considerations alone.

The survey questionnaire asked for number of faculty, which allowed NSF to tabulate median expenditures on a per-full-time faculty and per-full-time research-faculty basis, in addition to the analysis of spending on a per-unit basis.

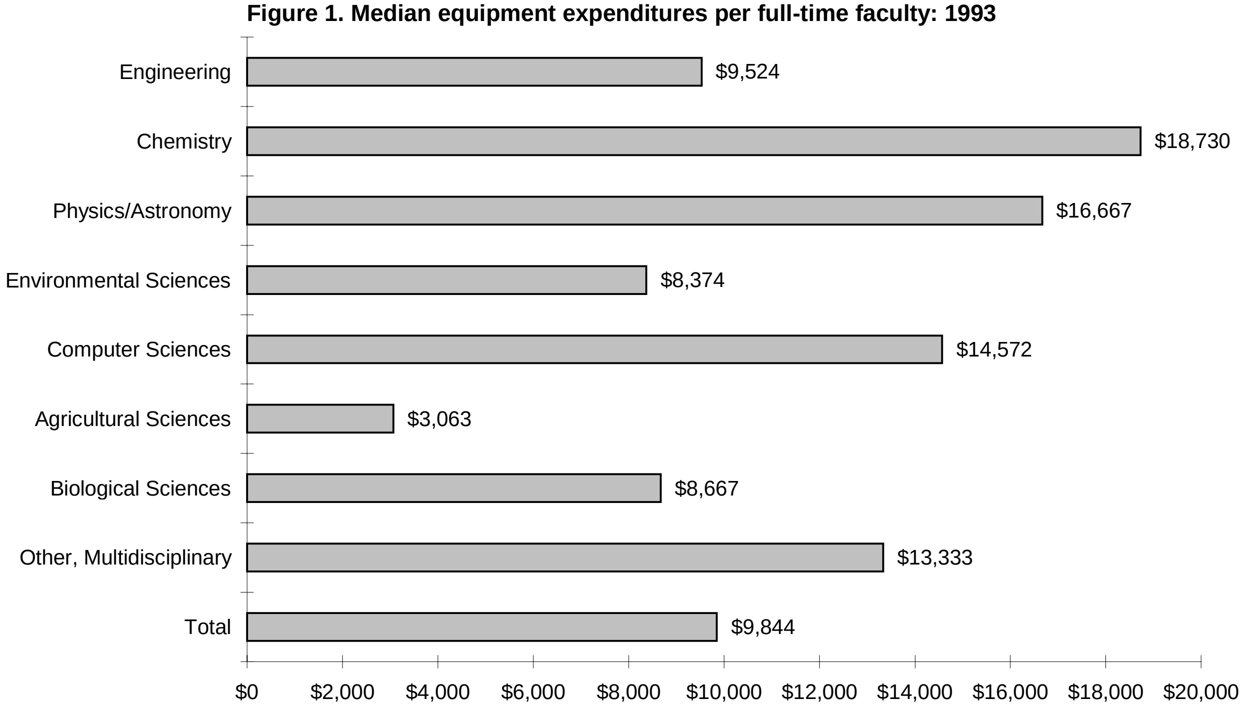
The Question

Respondents to this survey were asked to give the "number (headcount) of FULL-TIME faculty members in your unit" and the "number (headcount) of FULL-TIME faculty members in your unit who are participating in separately budgeted research projects."

Findings

Expenditures per Faculty Member.—The median expenditure per faculty member in 1993 for the purchase of research instrumentation by the units covered by this survey was $9,844. The field of research made a large difference in the level of expenditures: Median outlay per faculty member ranged from a high of $18,730 in chemistry to a low of $3,063 in the agricultural sciences (figure 1).

Figure 1. Median equipment expenditures per full-time faculty: 1993



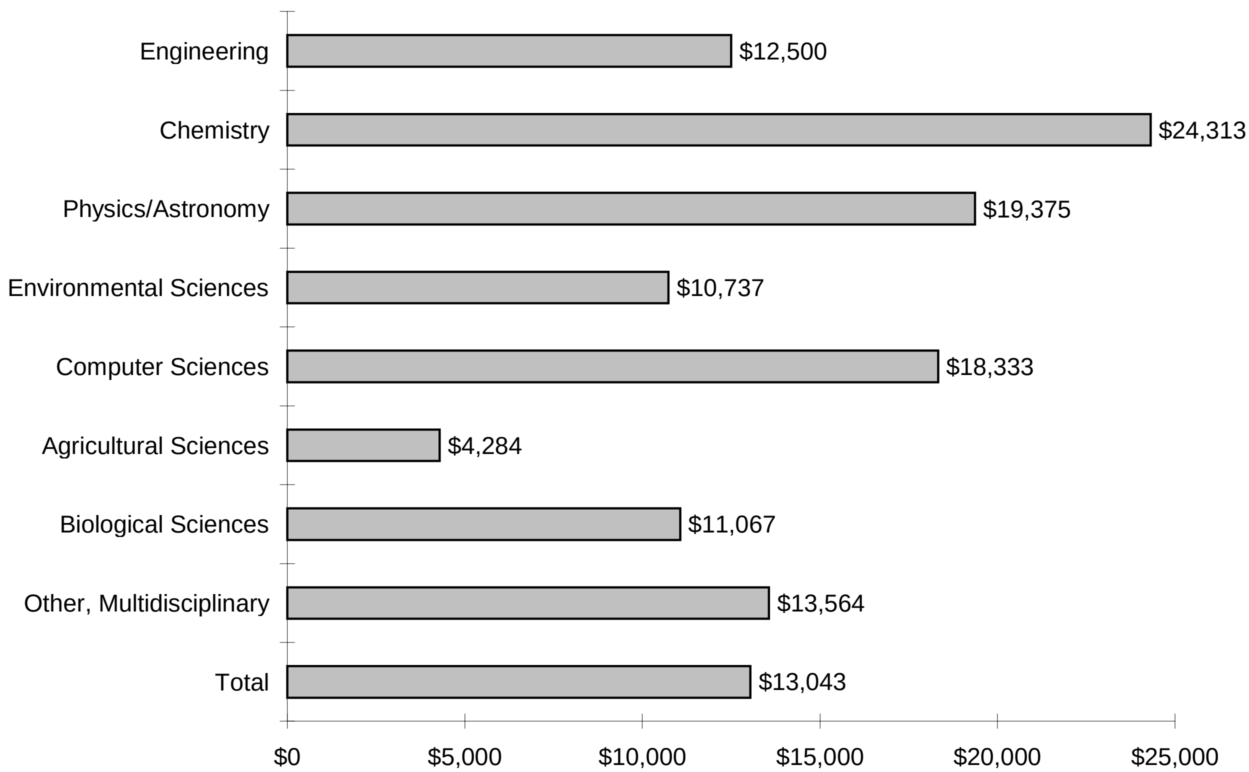
SOURCE: National Science Foundation/SRS, Survey of Academic Research Instruments and Instrumentation Needs: 1993

The type of unit also made a difference: Median expenditures per-faculty in the larger units were considerably higher ($24,200) than the per-faculty expenditure at the smaller units ($8,700).

Expenditures per Research-Faculty Member.—Although one usually associates the faculty with research at these large research-intensive universities, all faculty do not necessarily conduct research, nor conduct it during every year. For this reason the median expenditures per research-faculty member among the units responding to this survey were higher than the median per-faculty expenditure, reaching just over $13,000 in 1993 (figure 2). As in other instrumentation expenditure data, the field of science made a large difference in the expenditures: Median expenditures ranged from a high of $24,313 per research-faculty in chemistry to $4,284 in agricultural sciences.

The size of the largest instrument in the unit also made a difference in the per faculty costs. The larger units expended $26,200 per research-faculty member, compared with an $11,800 outlay by the smaller units.

Figure 2. Median equipment expenditures per full-time research faculty: 1993



SOURCE: National Science Foundation/SRS, Survey of Academic Research Instruments and Instrumentation Needs: 1993

TRENDS SINCE 1982–83 IN EXPENDITURES BY THE SMALLER UNITS

Data Considerations

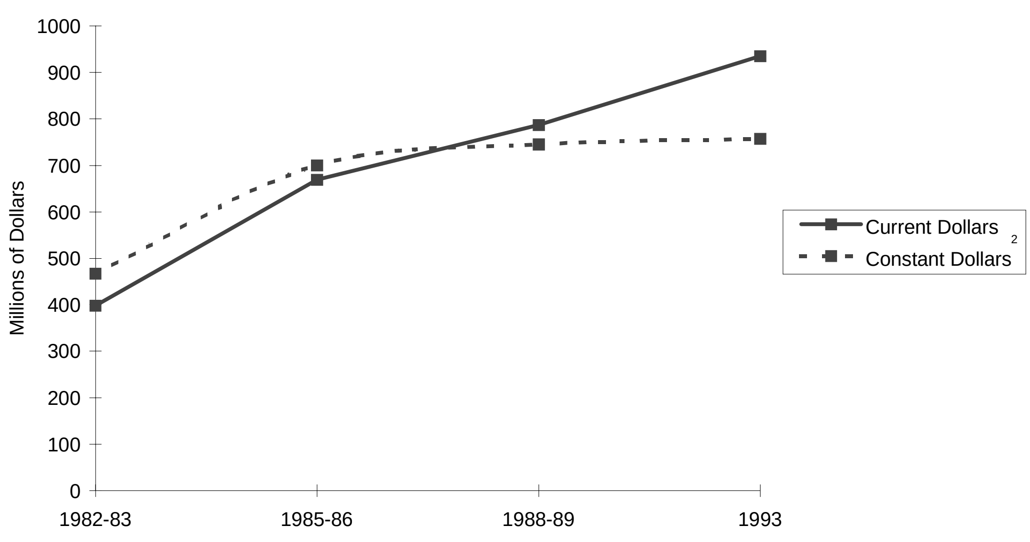
Over the years since the first instrumentation survey in 1982, there have been additions made to the types and the cost range of the instruments that were considered in scope. Therefore, trend data back to 1982 are available only for one category of respondents—those in the smaller units (in which all instruments cost less than $1 million). As would be expected, in most fields the *aggregate* expenditures for research instruments are generally higher for the smaller units, because these units outnumber the larger units (in which at least one instrument costs $1 million or more) (table 1). The exception is in computer science facilities, where the bulk of the expenditure cost is in the larger units, which typically house large mainframe computers.

Expenditures By The Smaller Units For The Purchase Of New Instruments

Total expenditures.— Total expenditures for the smaller units increased from $398 million in 1982–83 to $935 million in 1993 (table 1), an average annual increase of approximately 9 percent. However, figure 3 demonstrates that the greatest rate of increase in current dollars occurred between the 1982–83 and 1985–86 surveys (an approximate 19 percent annual increase). Since the 1985–86 survey, expenditures for purchases of academic research instrumentation in current dollars have risen more slowly (approximately 4 percent per year).

The change in the rate of increase was more dramatic in constant dollars. The total average annual increase since 1982–83 was approximately 5 percent. However, the constant dollar annual rate of increase, which was approximately 14 percent between 1982–83 and 1985–86, fell to an annual increase of approximately 1 percent between 1985–86 and 1993 (figure 3).

Figure 3. Expenditures for research equipment in the "smaller" units[1]: 1982-93



[1] Departments and facilities with no research instruments having an original purchase price of $1 million or more
[2] Using the GDP price deflator and a base year of 1987

SOURCE: National Science Foundation/SRS, Survey of Academic Research Instruments and Instrumentation Needs

Median expenditures per unit.—Normalized on a per-unit basis, the median expenditures of the smaller units also changed direction since 1985–86. Median expenditures increased at a rapid rate in current dollars between the 1982–83 and the 1985–86 surveys, but have been virtually level ever since (figure 4). In constant dollars, median expenditures per unit for the purchase of additional equipment have registered declines in every survey since 1985–86.

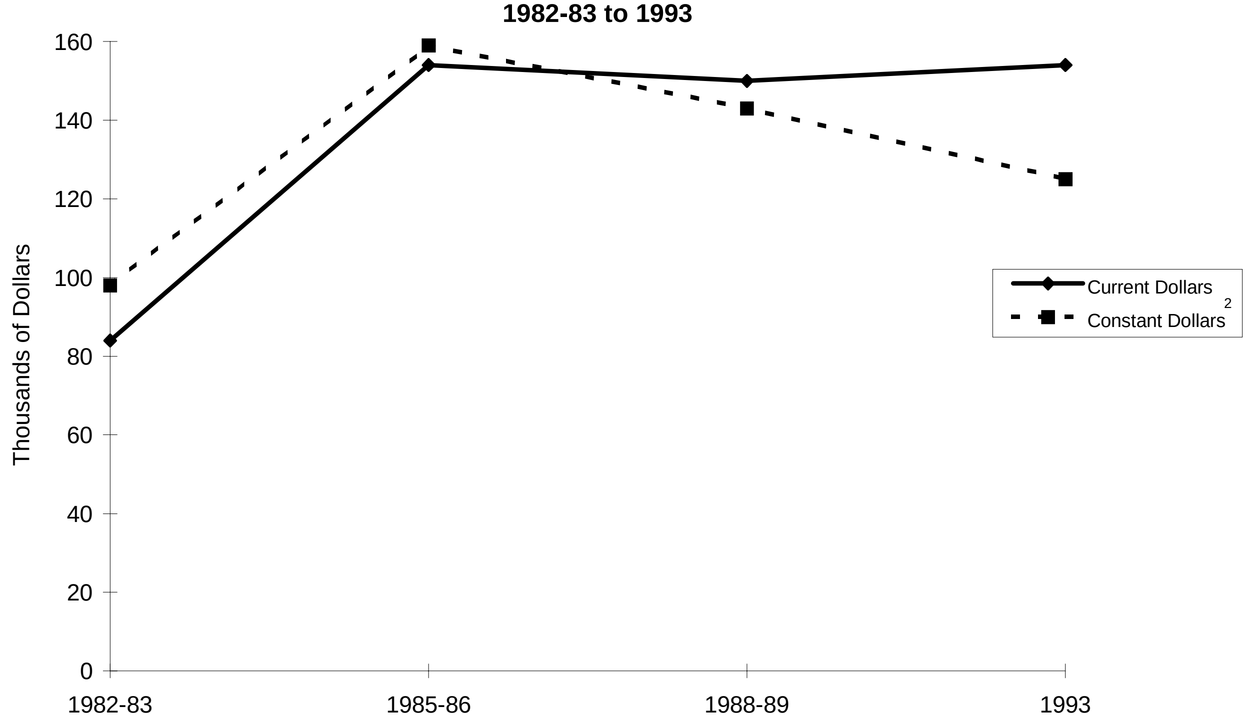
Expenditures by source of funds.—Federal funding as a proportion of total funding for the smaller units decreased from 50 percent in 1982–83 to 46 percent in 1993 (table A-5). State government contributions also declined (from 11 percent to 9 percent). Industrial contributions remained level, at 8 percent of total expenditures.

Institutions’ own funding rose from 24 percent in 1982–83 to 27 percent. “Other” sources, which include foundation and individual donations and bonds, rose from 7 percent to 10 percent.

Expenditure Trends by Field.— Smaller units in engineering experienced the greatest absolute increase in research instrumentation expenditures in current dollars: The $260 million in 1993 was almost three times larger than the $93 million in 1982–83. Smaller units in the biological sciences also experienced a large absolute increase: The $279 million spent in 1993 was more than twice the $130 million spent in 1982–83 (table 1).

In terms of proportional change, the largest percentage increase in expenditures since 1982–83 was in the computer sciences. This is not surprising, given the relative newness of the research field in the early 1980s, and the phenomenal increase in research computer capacity in recent years. Starting from the low base of $16 million in 1982–83, computer science expenditures rose 262 percent to $58 million in 1993.

Figure 4. Median expenditures for research equipment per "smaller" unit[1]: 1982-83 to 1993



1 Departments and facilities with no research instruments having an original purchase price of $1 million or more
2 Using the GDP price deflator and a base year of 1987

SOURCE: National Science Foundation/SRS, Survey of Academic Research Instruments and Instrumentation Needs

Agriculture was the only field of science that failed to double its expenditures since 1982–83, when expenditures were $27 million. Expenditures increased 52 percent to $41 million in 1993. That increase, however, was 6 percent in constant dollars, an increase of less than 1 percent a year.

Expenditures by the Smaller Units for Maintenance/ Repair and Operation of Existing Instruments

Trend data for the smaller units are also available for maintenance/repair costs back to the first survey in 1982–83. Survey questions about operation expenses, however, were only introduced with the 1987–88 survey (table A-1).

Findings

Maintenance/repair.—Expenditures for maintenance/repair in the smaller units decreased in 1993 for the first time since 1982–83. The $162 million spent in 1993 was 6 percent less than the $173 million spent in 1988–89 (table A-1). Median expenditures per unit decreased from $38,000 in 1988–89 to $25,000 per unit in 1993 (table A-6).

Maintenance /repair includes expenditures for service contracts and field service, salaries of maintenance personnel, tools, supplies, etc. In previous surveys, service contracts and field service comprised slightly more than 40 percent of total maintenance/repair expenditures. (This question was not asked on the 1993 survey, because of respondent burden issues.)

Operation.—Data for operation expenses were collected beginning with the 1988–89 survey. Median expenditures for smaller units dropped between the two surveys from $60,000 to $40,000 per unit. In the 1988–89 survey, respondents were asked to provide a breakdown of costs between salaries to operate the equipment and all other costs. Salaries comprised most of the costs in the smaller units. More than half of the respondents, in fact, had no operation expenses other than salaries. The larger units, by contrast, had median costs of $217,000 for salaries and $80,000 for other expenses (table A-7).

SECTION C.

AN ASSESSMENT OF NEEDS FOR ACADEMIC RESEARCH INSTRUMENTATION

DATA CONSIDERATIONS

Respondents were asked about expenditures for research instrumentation purchases on the basis of their actual 1993 expenditures, and the analysis and tables in the previous sections reflect those expenditures. Respondents were also asked for their perception of the needs of their units *at the time they were filling out the survey form in 1994*. For this reason, tables and analysis in this report concerned with the respondents' perceptions of the adequacy their current instruments, and the need for new instrumentation, reflect the *collection date* of late 1994.

The Question

Respondents were given a five-point rating scale ranging from "substantially increased" (1) to "substantially decreased" (5), and were asked to assess, "over the past two years, the needs for research equipment in my unit."

Findings

Overall, 69 percent of respondents reported that their needs had increased in the two-year period: Forty-five percent said that their needs had increased, and an additional 24 percent said that their needs had increased substantially. Thirty percent said that the needs had remained about the same, while only 2 percent reported that the needs had decreased (table A-8). Thus, for many disciplines, increased needs since 1992 were set against a leveling of expenditures since the 1988–89 survey (table 1).

ADEQUACY OF CURRENT EQUIPMENT TO MEET RESEARCHERS' NEEDS

The Question

To set the context for specific questions about needs, respondents were asked about the capability of their current instrumentation. Given a five-point scale ranging from "excellent" (1) to "poor" (5), they were asked to rate "the overall capability of the research equipment in (my) unit to enable existing faculty investigators[12] *to pursue their major research interests."*

Findings

Overall, 42 percent of the respondents from the larger institutions gave ratings of less than adequate to the capability of their research instruments to enable the faculty to pursue their major research interests. Respondents with the highest percentage reporting inadequacy were from chemistry (61 percent) and from computer science *facilities* (51 percent). However, only 26 percent of computer science *departments* rated their instrumentation as inadequate. A large minority in several other fields reported inadequacy: Forty-nine percent of respondents in engineering and in physics/astronomy, and 46 percent of environmental respondents. Agriculture (35 percent) and biology (32 percent) were the fields with the lowest percentage of respondents reporting inadequate equipment (table A-9). As the modal response, 39 percent of the respondents rated their instrumentation as inadequate to support the research interests of their faculty—a rating of 4 on the five-point scale (table A-9).

The Question

If the respondents answered that the instrumentation was "inadequate" or "poor," they were asked to estimate "the cost to acquire sufficient research equipment that would fully support your existing faculty."

Findings

The 42 percent of respondents who rated their instruments as being less than adequate estimated that it would cost a total of $1,438 million to bring their research instrumentation to a point that would fully enable existing faculty to pursue their major research interests. Engineering respondents recorded the highest amount necessary, $435 million. On a median cost-per-unit basis however, engineering

[12] It is important to note that respondents were asked to rate the capability of instrumentation for *the existing faculty* currently in place at the institution. Although it might be in the best interest of any individual institution to need different equipment to hire a new faculty member, on a national basis it was not appropriate to include this kind of need in the aggregate.

needs at $500,000 were in the mid-range of costs: The median per unit cost to acquire this equipment ranged from $950,000 in chemistry to $250,000 in the agricultural and multidisciplinary sciences (table 6). (See also the special analysis of the comparison of needs of these respondents with those who rated their instrumentation as adequate, beginning on page 33.)

TOP-PRIORITY ITEMS OF NEED

Presentation of the Data

As would be expected from so large a cohort of respondents, responses to this question yielded a great amount of data. To assist in user analysis, the data are presented in several tabular ways, allowing the researcher to review the data by type of instrument needed, as well as by discipline. It is not appropriate in a report of this type to describe each table in great detail. Instead, for the convenience of the reader, the text will highlight the different types of analyses that can be derived from the data, and indicate the tables where the information can be found.

The sampled instruments were tabulated into five major categories: computers; chromatographs and spectrometers; microscopy instruments; bioanalytical instruments; and "other" instruments.

Readers wishing to ascertain the cost of acquiring the most needed instruments will find that table 7 presents data on the total cost of the top priority item and the top three priority items needed, disaggregated by field of science or engineering.

Appendix table A-10 presents the cost of acquiring the needed instruments on a per-unit basis, by displaying the median cost, disaggregated by major instrument category and by field. Table A-10 also shows how popular the five major categories of instrument were, by presenting the frequency of requests by respondents for them.

Appendix table A-11 gives greater detail on the top priority items shown in table 7; table A-11 presents total cost in dollars for each major category of instrument. It also depicts the concentration of need within fields. For instance, the cost of the top priority items requested by respondents in two fields represented 51 percent of the total cost: The requests of respondents in engineering and in physics/ astronomy were 27 percent and 24 percent of the total cost, respectively. (Table A-12 presents identical data to table A-11 for the top *three* priority instruments combined.)

Finally, for researchers who want to know which types of instruments are needed by individual disciplines, table 8 presents the greatest amount of detail (i.e., the total cost of the top priority instruments by detailed type of instrument). (Table A-13 presents identical data to table 8 for the top *three* priority instruments combined.)

Context

The rating-scale questions on capability discussed above were asked in terms of the *overall* capability of the stock of existing instrumentation to enable current faculty to pursue their major research interests. In a slight variation of that question, respondents were requested to name three pieces of equipment that were most needed to bring the unit's research equipment up to the faculty's full capabilities. While 58 percent of the respondents were satisfied with the overall capability of the instrumentation (see discussion above), 90 percent had some need for additional items.

The Question

Respondents were asked to indicate "The three pieces of equipment, costing $20,000 or more (including the cost of accessories), that are most needed to bring your unit's research equipment up to your faculty's full capabilities." They were asked to list these three top items in priority order and to estimate the purchase price of each item.

(Realizing that not all needed instruments were in this high-cost category, particularly since many very high-powered personal computers and workstations can be purchased for less than $20,000, the questionnaire also allowed respondents to respond that no additional equipment costing more than $20,000 was needed, which 10 percent of respondents did. The findings below are based on the 90 percent of respondents who indicate that their topmost priority was for instruments over $20,000.)

Table 6. Percent of respondents who reported their instrumentation was not adequate to enable faculty to pursue their major research interests, and the estimated cost to acquire sufficient research instrumentation to support faculty fully, by field of science and engineering: 1994

[Dollars in thousands]

Field of science and engineering	Percent reporting inadequate instrumentation	Total cost to achieve sufficiency	Median cost per unit	Mean cost per unit
Total	42%	$1,437,533	$500	$783
Engineering	49	435,314	500	729
Chemistry	61	133,376	950	989
Physics/astronomy	49	199,448	560	1,363
Environmental sciences	46	223,702	500	1,203
Computer science	38	75,931	500	893
Academic departments	26	20,485	S	S
Computer facilities	51	55,447	450	1,269
Agricultural sciences	36	69,210	250	761
Biological sciences	32	241,282	350	480
Other, multidisciplinary	48	59,269	250	645

NOTES: Data are for the 42 percent of the respondents who reported on a scale from 1 (excellent) to 5 (poor), that the overall capability of research instruments to enable existing faculty investigators in their unit to pursue their major research interests was inadequate or poor (a score of 4 or 5).

Because of rounding, details may not add to totals.

KEY: S = fewer than 10 cases for analysis

SOURCE: National Science Foundation/SRS, Survey of Academic Research Instruments and Instrumentation Needs: 1993

Findings

If all three of the top priority items needed by each respondent could be purchased, the total estimated cost would be $2,048 million. Of this amount, $942 million, or 46 percent of the total, was the estimated cost of acquiring only the topmost priority item (table 7).

NEED BY TYPE OF INSTRUMENT

Computers.—Twenty-eight percent of all respondents listed a computer as their topmost priority, a graphic illustration of the importance of computers to research in all fields. The range of top priority needs for computers went from highs of 100 percent of respondents in computer science departments and 35 percent in engineering and the environmental sciences, to a low of 14 percent of respondents in chemistry and biology (table A-10).

The cost to acquire only computer top-priority items was $202 million, or 21 percent of the total cost of all first-priority items. The leading fields by cost were computer sciences ($99 million) and engineering ($48 million) (table A-11).

The median cost for all computers listed as top priority was $75,000 (table A-10). As would be expected, the median cost cited by computer science facilities was much higher than that reported in other fields, $200,000. This reflects the high cost of mainframes and supercomputers needed by the central facilities still operating for research, many of which perform computations for off-site researchers.

Chromatographs and spectrometers.—The total cost for all chromatographs and spectrometers listed as top priority need was $213 million, and 21 percent of respondents reported them as their top priority need (table A-10). The majority of need was in biology ($62 million), chemistry ($57 million), and engineering ($53 million). Proportionately, however, chemistry respondents had the highest demand for these instruments ($57 million out of $62 million). This category includes NMR/EPR spectrometers as well as instruments such as x-ray diffraction systems. In terms of cost, most of the need cited by chemistry respondents was allocated to NMR/EPR spectrometers, which comprised 83 percent of the cost of the top priority instruments mentioned by the chemistry respondents.

Bioanalytical instruments.—The total cost for all bioanalytical instruments listed by respondents as the top priority need was $76 million, and 20 percent of all respondents mentioned this category as their top priority item (table A-10). As would be expected, respondents from biology fields expressed the highest need—$36 million, or 47 percent of the total cost. Respondents in physics/astronomy also needed a sizable amount of bioanalytical instruments, totaling $19 million, or 25 percent. The need in engineering fields comprised $11 million, or 15 percent (table A-11).

Microscopy instruments.—The total cost of the top priority items in microscopy was $76 million, the same total as for bioanalytical instruments. However, fewer respondents cited a need for this category (11 percent) than for bioanalytical instruments (20 percent). Respondents from the biological sciences cited a need for 47 percent of the total cost of top priority microscopy instruments, $36 million. Thirty-one percent of the total cost, or $24 million, was needed by respondents from the engineering fields (table A-11). Engineering respondents reported that the bulk of their need was for electron microscopes (table 8).

"Other" instruments.—"Other" instruments was used to describe miscellaneous instruments, none of which was large enough to constitute a category of its own. Taken together, however, "other" comprised the largest category of need, both in terms of total cost as well as the percentage of respondents mentioning the item. Twenty-nine percent of respondents cited "other" instruments as their top priority needs (table A-10). The $375 million cost comprised 40 percent of the total cost of all top priority items (table A-11).

"Other" instruments includes lasers, robots, temperature/pressure control devices, and "major instruments," the most costly single type of instrument requested. ("Major instruments" are often unique, individually fabricated items—such as nuclear reactors, research vessels, wind tunnels, and telescopes). Because each major instrument is very costly, it is not surprising that the $375 million total cost is the highest of all the categories.

Table 7. Total cost to purchase the top priority item and total cost to purchase the top three priority items requested, by field of science and engineering: 1994

[Dollars in millions]

Field of science and engineering	Total cost	
	Top priority item	Top three priority items
Total	$942	$2,048
Engineering	255	534
Chemistry	62	146
Physics/astronomy	227	558
Environmental sciences	104	200
Computer science	99	146
Academic departments	21	42
Computer facilities	77	104
Agricultural sciences	15	49
Biological sciences	163	363
Other, multidisciplinary	18	52

NOTES: Data are for the 90 percent of respondents who reported a need for instruments costing $20,000 or more. The remaining 10 percent of respondents reported that their units did not need any additional instrumentation in that price range.

Because of rounding, details may not add to totals.

SOURCE: National Science Foundation/SRS, Survey of Academic Research Instruments and Instrumentation Needs: 1993

The need for “other” instruments as a top priority was not uniform throughout the sciences, but was heavily concentrated in physics/astronomy ($190 million, with 59 percent of the respondents mentioning items in this category), engineering ($119 million, 32 percent), and environmental sciences ($48 million, and 19 percent.) (Table A-10 shows the percentage of respondents requesting a particular category of instrument. Table A-11 shows the dollar cost for each category of instrument.)

TOP PRIORITY ITEMS OF NEED BY DETAILED TYPE OF INSTRUMENT

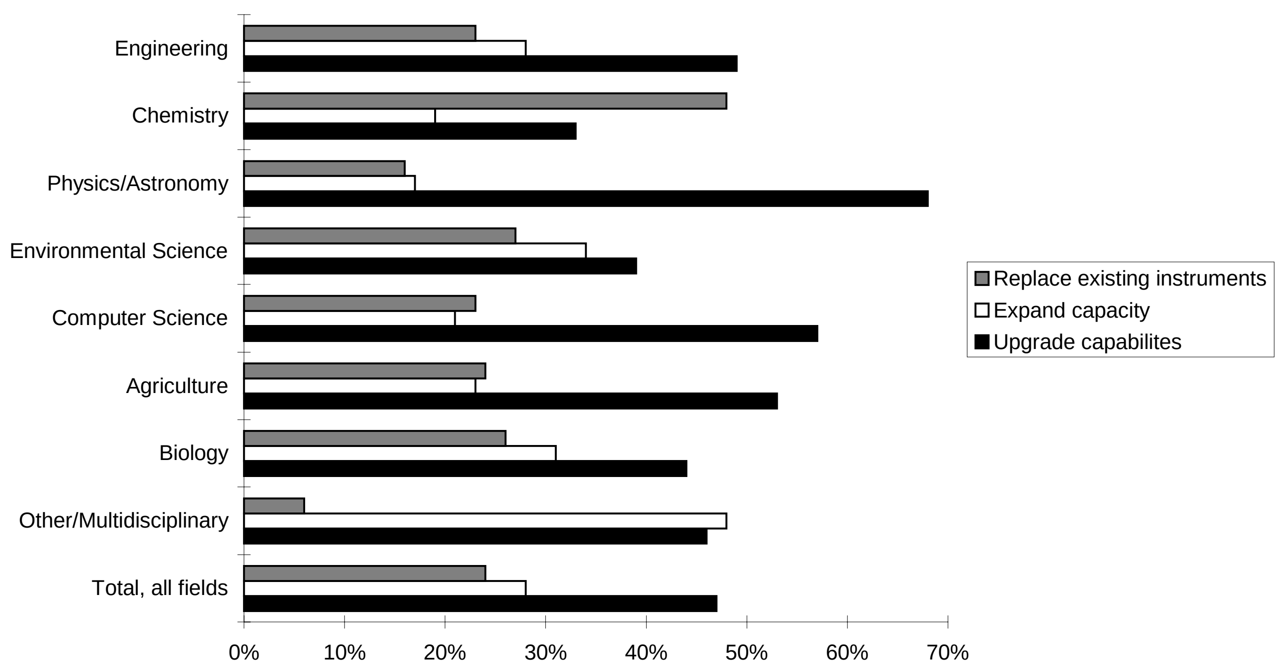
While table 7 depicts the total cost of the top priority item and the top three priority items by each field of science, table 8 presents a detailed picture of the exact types of instruments needed, by field of science, and the total cost of each top priority item. The reader can find information on the types of instruments needed, the magnitude of the need, and the concentration of instruments within the fields of science. For example, only computers were listed by respondents in every field as the top priority item needed in their units. (Table A-13 presents identical data to table 8 for the top *three* priority instruments combined.)

REASONS FOR NEEDING THE TOP PRIORITY ITEMS

The Question

When listing the three topmost priority items needed by the unit, the respondents were asked to “state the primary purpose for acquiring the instrument—whether to (1) replace an existing item; (2) expand capacity—i.e., more copies of existing equipment; or (3) upgrade capabilities—i.e., perform experiments that you cannot do now.” It must be understood that in many cases these reasons are not mutually exclusive—for example, few researchers replace an existing item with its exact replica; today’s instruments are often better, faster, and more complex than their predecessors.

Figure 5. Reason for need for the highest priority research instrument, by field of science and engineering: 1994



SOURCE: National Science Foundation/SRS, Survey of Academic Research Instruments and Instrumentation Needs: 1993

Table 8. Total cost to purchase the top priority item requested, by type of instrument and field of science and engineering: 1994

[Dollars in thousands]

Type of instrument requested	Total	Engi- neering	Chemistry	Physics/ astronomy	Environ- mental sciences	Computer science	Agricul- tural sciences	Biolog- ical sciences	Other, multi- disci- plinary
Total, all instruments	$941,894	$254,750	$62,172	$226,842	$104,163	$98,745	$14,807	$162,801	$17,613
Computers and data handling instruments	201,867	47,924	4,455	9,587	22,553	98,614	2,811	15,165	757
Graphics/CAD/imaging computer systems	54,406	13,974	3,267	2,088	5,605	16,265	1,544	11,285	379
Other computers/components > $50,000	141,988	32,107	1,188	7,340	14,876	81,881	1,164	3,098	333
Other computers/components < $50,000	5,473	1,843	0	159	2,072	467	103	782	45
Chromatographs and spectrometers	212,566	53,099	56,831	6,305	23,271	0	4,226	62,404	6,430
Electron/auger/ion scattering	4,464	387	0	3,522	0	0	427	0	128
Electron spectroscopy/photo-induced emission elemental analyzer	4,726	1,836	0	2,267	0	0	0	623	0
NMR/EPR spectrometer	126,305	28,903	51,463	0	3,868	0	0	40,464	1,608
UV/visible/infrared spectrophotometer	1,468	1,083	223	0	0	0	107	55	0
Xray diffraction systems	14,410	888	2,030	420	2,152	0	59	8,862	0
Chromatographs and elemental analyzers	18,117	7,090	0	0	5,731	0	1,516	3,659	121
Other spectroscopy instruments	43,076	12,912	3,116	96	11,520	0	2,118	8,741	4,573
Microscopy instruments	76,437	23,863	589	1,757	9,725	0	520	36,270	3,713
Electron microscopes	38,227	17,970	0	1,435	7,706	0	335	10,781	0
Other microscopy instruments	38,209	5,892	589	323	2,019	0	185	25,488	3,713
Bioanalytical instruments	75,968	11,161	0	19,208	632	0	3,960	35,850	5,156
Cell sorters/counters, cytometers	4,155	0	0	0	60	0	0	3,098	997
Centrifuges and accessories	12,959	217	0	0	547	0	1,795	10,400	0
DNA/protein synthesizers/sequencers/ analyzers	22,370	0	0	0	0	0	647	17,610	4,113
Growth/environmental chambers	13,388	10,831	0	234	25	0	1,008	1,291	0
Scintillation/gamma radiation/counters/ detectors	23,096	113	0	18,975	0	0	511	3,452	45
Other instruments	375,057	118,703	296	189,985	47,982	132	3,289	13,112	1,558
Electronics instruments (cameras, etc)	4,123	1,493	0	134	109	0	0	2,089	298
Temperature/pressure control/ measurement instruments	4,787	3,482	0	102	779	0	424	0	0
Lasers and optical instruments	21,213	13,778	296	4,265	0	0	0	2,339	536
Robots, manufacturing machines	7,502	5,756	0	1,745	0	0	0	0	0
Major instruments (telescopes, ships, nuclear reactors, wind tunnels, etc)	247,545	30,434	0	173,168	41,971	0	1,746	0	226
Other, not elsewhere classified	89,888	63,760	0	10,572	5,122	132	1,120	8,684	498

NOTE: Data are for the 90 percent of respondents who reported a need for instruments costing $20,000 or more. The remaining 10 percent of respondents reported that their units did not need any additional instrumentation in that price range.

Because of rounding, details may not add to totals.

SOURCE: National Science Foundation/SRS, Survey of Academic Research Instruments and Instrumentation Needs: 1993

Findings

Overall, 47 percent of respondents in all fields reported that the primary reason they needed the top priority research instrument was to "upgrade capabilities" for the unit, i.e., to perform experiments that they "cannot do now." This was the modal response for all fields except chemistry, where only 32 percent of respondents mentioned this need. (At the same time, 48 percent of respondents in chemistry cited "replace an existing item" as their primary reason for the need (figure 5). Only 25 percent of respondents overall reported that they needed the item to replace existing equipment.)

Twenty-eight percent of all the respondents cited expanding capacity, or the need for more copies of a particular item, as the primary reason for need.

SPECIAL ANALYSIS: MEASURING NEEDS

Issue 1—Specific items on the questionnaires

Context

It is very difficult to devise a questionnaire that will produce national estimates of the pressing needs for research instrumentation in academia. Questions must be devised so that the national estimates reflect the mix of need; that is, it is recognized that some units are always highly successful in obtaining the bulk of their most needed instrumentation, while others seem always to be in dire need. The survey's national estimates must reflect the needs of both of these types of units. Therefore, the instrumentation survey questionnaire asked about need in two ways:

- *All respondents were asked to list the highest and top three highest priority needs in their units.* Since these questions were asked of department chairs, who have an overall sense of the most important research instruments, asking for the top three needs would give an accurate picture of the cost of the immediate needs within all the units.
- *Respondents who had reported that they had inadequate instrumentation for their faculty's needs were asked to estimate what it would take to bring their instrumentation up to a level that would support their faculty.* This question, added to the survey in 1993, captured the remedial cost of upgrading instrumentation to bring it to a level that would support the faculty in those units that currently had inadequate instrumentation.

Issue 2—Comparisons of costs of top priority needs with costs to correct overall inadequate instrumentation

Context

Short of analyzing the internal records of every respondent, there is no definitive way to determine whether the reported top priority needs reflected the respondents' true needs, or were a "wish list" of instruments that would be helpful. It has been assumed that respondents reply to the survey in good faith, and that an enumeration of their three most pressing top priority needs represents some portion of their total needs. However, the addition of the new question added to the 1993 survey makes it possible to analyze the relationship between the top three priority needs of the group whose instrumentation is inadequate, and the amount to bring the instrumentation up to support their faculty's research needs. Presumably, the top three priority needs would indicate the most pressing needs, and not equal the entire amount of expenditures necessary to support the existing faculty.

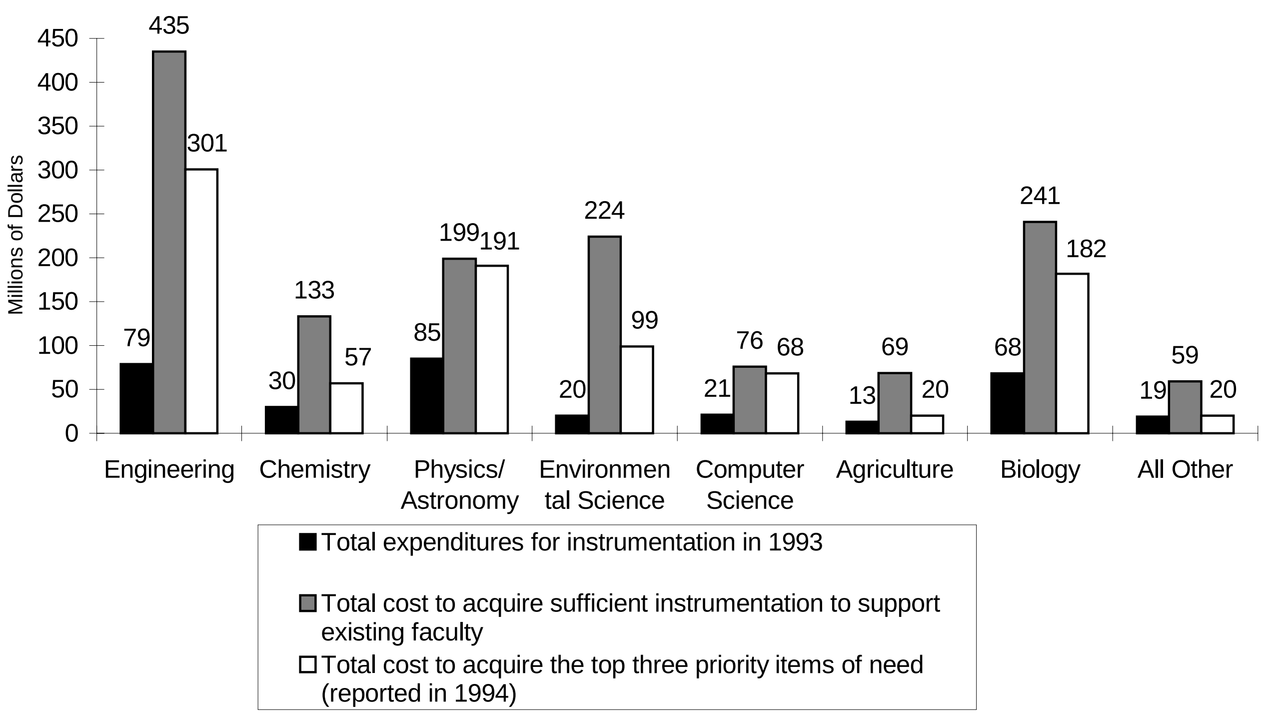
Findings

In all fields, this was exactly the case: The cost of the top priority items needed by the "inadequate" group ($939 million for all fields) was less than the estimated cost to "fix" their entire instrumentation needs ($1,438 million). Closest in total were the needs of the computer science respondents, where the $68 million in three "top priority" needs was 89 percent of the cost to bring instrumentation up to a level that would satisfy the faculty (figure 6). This is not surprising, as the addition of three state-of-the art computers in any one "inadequate" unit would make a major impact on the ability of the faculty to conduct research effectively.

The largest *percentage* disparity was in agriculture. The $20 million cited as the total cost of their three top priority needs was only 29 percent of the cost of bringing the inadequate group's instruments up to a level that would completely satisfy the faculty's needs. The largest *cost* disparity was in engineering. Respondents reported a total need of $435 million, or $134 million more than the cost of acquiring their three top priority needs. The $301 million in top priority needs was 69 percent of what would be needed to bring the instrumentation up to the needs of the faculty.

The needs of the "inadequate" group were also compared with their level of spending in 1993. In all fields the cost cited to acquire sufficient instrumentation during the survey collection period in 1994 was several times the level of expenditures that they were able to achieve in 1993 (figure 6). The largest disparity was in engineering. At $79 million, the "inadequate" group's 1993 expenditures for new purchases were the second highest of all fields. Nevertheless, they estimated that it would take an additional $435 million to bring their instrumentation up to a level that would satisfy the needs of the current faculty.

Figure 6. Respondents who reported inadequate instrumentation for faculty investigators: total expenditures in 1993 and needs reported in 1994



SOURCE: National Science Foundation/SRS, Survey of Academic Research Instruments and Instrumentation Needs: 1993

Issue 3—Comparisons of the data reported by respondents reporting adequate and inadequate instrumentation

Context

An analysis was made to determine the extent of related differences, for both expenditures and needs, in the data reported by the 42 percent of respondents who rated their instruments as less than adequate for their faculty's research needs, compared with the 58 percent who reported their instruments as adequate.

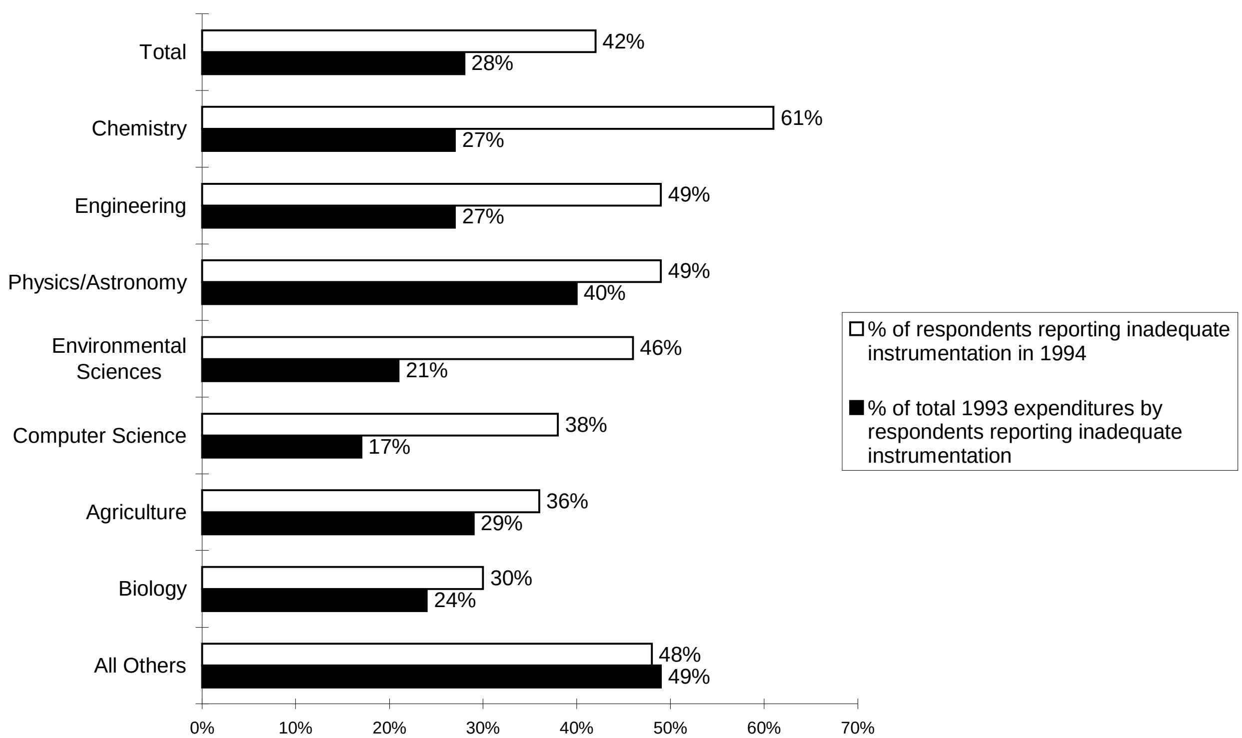
Findings

The "inadequate" group as a whole had lower total purchases of new instrumentation in 1993, and lower median per-unit purchases, than did the "adequate" group. Conversely, perhaps reflecting the lower outlays, the total cost of the top priority need cited by the "inadequate" group ($507 million) was higher than total cost of the top priority need reported by the "adequate" group ($436 million). The total cost of the top three items needed by respondents, however, was higher for the "adequate" group ($1,111 million) than for the "inadequate" group ($939 million).

1993 Expenditures.—Lower yearly expenditures perhaps point to much of the cause of dissatisfaction in the "inadequate" group. Figure 7 illustrates that this group spent less than their proportionate share in new research instrumentation in 1993. The 42 percent reporting inadequate instrumentation spent $334 million on new purchases during 1993, only 28 percent of the total. The 58 percent reporting adequate instrumentation spent $870 million, or 72 percent. (On a per-unit basis, the median expenditure by the "inadequate" group was $100,000, versus $235,800 by the "adequate" group.)

In some fields the "inadequate" group reported particularly low proportions of total expenditures. In chemistry, the 61 percent reporting inadequate instrumentation made just 27 percent of the total purchases in chemistry in 1993. In computer science, the 38 percent reporting inadequate instrumentation made 17 percent of the total purchases in 1993.

Figure 7. Respondents who reported inadequate instrumentation for their faculty



SOURCE: National Science Foundation/SRS, Survey of Academic Research Instruments and Instrumentation Needs: 1993

PRICE-RANGE OF OPTIMAL FEDERAL FUNDING

The Question

Respondents were asked to state the price-range of instruments that would be most beneficial to faculty investigators in the unit, if increased Federal funding were possible.

Findings

The modal response of all the respondents was in the $20,000 to $49,999 range (30 percent stated that this price range was potentially the most beneficial.) Close behind, 29 percent of respondents mentioned the high-price range of $100,000 to $499,999 (table 9).

The majority of respondents in two fields replied that the most beneficial price-range area was under $50,000: agriculture (59 percent) and biology (54 percent). (See related discussion of median cost of top priority needs, above.) Their needed instruments tend to be less expensive than those needed in several other fields. It is therefore reasonable to expect that the price-range for most needed Federal funding, if available, would also be lower than for those other fields.

In contrast, only 13 percent of the chemistry respondents replied that the most beneficial price-range area would be under $50,000. The modal response for chemistry (51 percent) cited items between $100,000 and $500,000.

At the very upper end of the price range for most beneficial Federal funding, only 6 percent of all respondents cited a preference for the very expensive instrumentation over $500,000. The few fields whose respondents expressed a substantial need in this area were physics/astronomy (17 percent), chemistry (18 percent), and computer science facilities (51 percent).

The respondents from computer science facilities indicated a strong preference for the highest-priced items: Forty-two percent reported that the optimal range for Federal funding would be for instrumentation over $1 million. This finding is consistent with the previous discussion—many campuses no longer utilize their central computer facilities for research. For those that remain in the research domain, the trend is toward consolidation, with a need for very expensive mainframes and supercomputers. For example, as seen in table A-10, the median cost for a top priority computer for computer science facilities ($200,000) is far greater than the cost of the top-needed computer for any other discipline.

PERCEIVED LIMITATIONS OF CURRENT INSTRUMENTATION

The Question

Respondents were asked, "Are there any important subject areas . . . in which investigators in this (unit) are unable to perform critical experiments in their areas of research interest due to lack of needed equipment?"

Findings

In 1993, slightly more than half of all respondents (56 percent) reported that there were subject matters in which their faculty investigators were unable to perform critical experiments because needed equipment was lacking (figure 8). There has been a marked decrease in the percentage of respondents reporting this deficiency since 1983–84, when 74 percent of the respondents reported such limitations. The greatest decrease between 1983–84 and 1993 occurred in computer science, from 96 percent in the earlier survey, to 44 percent in 1993, the lowest percentage reported in any field.

Although there has been steady improvement in the availability of research instruments to academic researchers, the continued lack of specific instruments is a significant limitation for the scientific community, where a majority of respondents in all fields but computer science reported an inability to perform critical experiments because of a lack of instruments. The greatest proportional need occurred in other, multidisciplinary fields (66 percent of respondents), agriculture (65 percent), and physics/astronomy (64 percent) and chemistry (64 percent).

Table 9. Percent distribution of the price range of instruments for which increased Federal instrumentation funding would be most beneficial to units, by field of science and engineering: 1994

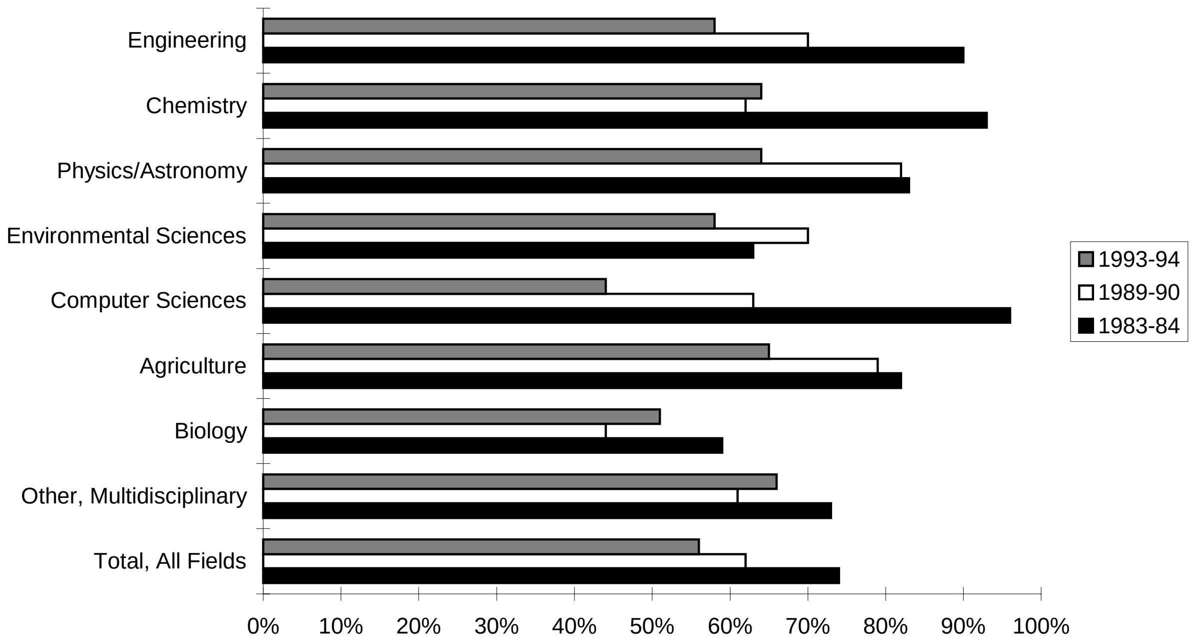
[Percent]

Field of science and engineering	Price range most beneficial						
	Under $10,000	$10,000-$19,999	$20,000-$49,999	$50,000-$99,999	$100,000-$499,999	$500,000-$999,999	$1,000,000 and over
Total	1%	12%	30%	21%	29%	3%	3%
Engineering	1	7	38	18	32	4	1
Chemistry	0	0	13	18	51	13	5
Physics/astronomy	0	3	19	26	35	9	8
Environmental sciences	1	2	24	25	43	3	2
Computer science	2	17	24	13	19	5	20
Academic departments	1	31	26	17	24	1	0
Computer facilities	2	1	23	8	14	9	42
Agricultural sciences	8	11	40	22	19	0	0
Biological sciences	1	21	32	20	25	1	1
Other, multidisciplinary	0	20	18	37	21	2	2

NOTE: Because of rounding, percents may not add to 100.

SOURCE: National Science Foundation/SRS, Survey of Academic Research Instruments and Instrumentation Needs: 1993

Figure 8. Percent of respondents reporting that their investigators cannot do critical experiments in their research areas, due to lack of needed instruments, by field of science and engineering: 1983-94



NOTE: No data are available for 1986–87.

SOURCE: National Science Foundation/SRS, Survey of Academic Research Instruments and Instrumentation Needs: 1993

SECTION D.

TECHNICAL NOTES

This section discusses the study methodology as well as various other technical aspects that the reader should consider when interpreting the data presented in this report. Where relevant, the discussion includes references to the three previous cycles of this survey. The following aspects are covered:

- definition of terms used in this report;
- universe and samples;
- two types of survey questionnaire;
- data collection schemes;
- changes in data collection procedures for cycle IV; and
- response rates, weighting, and reliability of survey estimates.

DEFINITION OF TERMS USED IN THIS REPORT

Department—a degree-granting academic unit
Facility—a non-degree granting academic unit
Faculty—includes tenured, non-tenured, teaching, and visiting faculty and researchers of faculty-equivalent rank; it does *not* include postdoctorates.
Maintenance/repair costs—includes maintenance agreements, service contract costs, salaries of department-provided or institution-provided maintenance/repair personnel, and costs of supplies, equipment, and facilities for servicing research instruments
Operation costs—includes salaries for technicians or other personnel paid to operate research equipment, and costs of supplies and materials used in operating the instruments
Research instrument (or research equipment)—any item (or interrelated collection of items comprising a system) of nonexpendable tangible property or software, having a useful life of more than 2 years and a cost of $500 or more, which is used wholly or in part for research
"System"—an interrelated collection of instrument items that effectively comprise one single item
Unit—denotes either a department or a facility

UNIVERSE AND SAMPLES

Institutions.—With slight additions to coverage in 1986–87, the instrumentation survey has been collected from the same panel of institutions since 1983. The first cycle of the survey was conducted in 1983–84. This baseline survey had a panel of 67 institutions: 43 colleges and universities and 24 medical schools. In the second cycle, conducted in 1986–87, the sample of colleges and universities was expanded to 55 schools, for a total of 79 in the panel of institutions. This same panel of 79 was used in both cycle III, conducted in 1989–90, and cycle IV, conducted in 1993 and 1994. The results of the 1993 survey, conducted in 1994, are presented in this report.[15]

This panel of 79 institutions was originally selected from the population of all institutions that each annually perform a minimum of $3 million in research and development. For each survey the results from the panel were generalized to the known universe of institutions that performed a minimum of $3 million in R&D in that year. For each survey this population in total accounted for more than 90 percent of the expenditures for academic R&D in science and engineering in the United States.

At the time of the 1993 survey, the latest year for which total R&D data were available was 1991; in that year there were 318 institutions that performed more than $3 million in R&D. Over the years in which the survey has been collected there has been a gradual increase in the number of institutions that perform more than $3 million in R&D. In cycle III the survey's panel of 79 institutions represented the 287 institutions that annually conducted more than $3 million in R&D. In cycle II it represented 174 institutions, and in cycle I, 155 institutions.

The panel of 79 institutions is divided into two samples:

The first sample (55 colleges and universities, excluding their medical components, if any) represents the 214 institutions that had R&D expenditures of more than $3 million in FY 1991.

[15] A major change was made to the methodology of the 1992 survey conducted in 1993. To relieve respondent burden, only the Department/Facility Questionnaire was used to gather instrumentation expenditures and needs, and the Instrument Data Sheet was not fielded in that year. Because of the major differences between that survey and all the others in the survey series, the 1992 survey results are not included in the trend data in this report. Other changes to the methodology in the cycle IV survey are described below in these technical notes.

The probability of selection for institutions in this sample was proportionate to the total expenditures for R&D for those S&E fields included in the survey.

The second sample (24 medical schools, including medical components of colleges and universities) represents the universe of 104 medical schools that received at least $3 million in extramural awards for research from NIH in FY 1991. The probability of selection for elements in this second sample was approximately proportionate to the total amount of dollars for extramural awards given to medical institutions by NIH.

These two samples were selected independently. There is some overlap in institutional affiliation between the two samples, but no overlap in units or research instruments covered. For example, 15 of the 55 institutions selected to be in the sample of R&D colleges and universities are affiliated with a medical school that was independently chosen to be in the sample of 24 medical schools. Conversely, if an institution in the sample of 55 R&D colleges and universities had a medical school that was not independently selected to be in the sample of 24 medical schools, data for that medical school were not collected for the survey. The institutions in both of these samples are listed in appendix B.

Departments and Facilities ("Units")

Within the sampled institutions, departments and facilities were considered in-scope for the survey if they:

1. had at least one instrument used for scientific research that had a minimum purchase price of $20,000; and
2. were in the science and engineering fields of agriculture, biology, computer science, environmental sciences, chemistry, astronomy/physics, and engineering. (A list of the subfields included under these major fields is included in appendix C.)

The sampled institutions contained a total of 1,541 in-scope departments and facilities. From these, a sample of 996 were selected to be surveyed. (In four fields that had large numbers of departments or facilities—engineering and the agricultural, biological, and environmental sciences—a sample was selected. In the remaining fields—chemistry, computer science, and physics/astronomy—all of the eligible departments/facilities were selected.)

The survey excluded as out of scope any of the 18 university-administered federally funded research and development centers (FFRDCs), as well as any units that might be housed on a university campus but not administered by the university.

The detailed sampling plan followed for selecting the departments and facilities is available in a separate methodology report, *National Survey of Academic Research Instruments and Instrumentation Needs, 1993: Methodology Report.*[16]

Questionnaires

In each cycle of the survey, two types of data have been collected from two different sets of respondents:

The heads of academic departments and research facilities complete a *Department/Facility Questionnaire* in which they provide data for their entire units regarding expenditures for purchasing research instruments, the sources of these funds, their provisions for maintaining and repairing the instruments, and an evaluation of all their research instruments in terms of adequacy, capabilities, and needs. This report describes the findings based on this questionnaire. A copy of the questionnaire is included in appendix D.

Principal investigators complete an *Instrument Data Sheet* in which they provide detailed data about individual pieces of research instruments (e.g., its adequacy for research, pattern of usage, and technical capabilities). Data based on this questionnaire will be available in a forthcoming companion report, C*haracteristics of Science and Engineering Instrumentation in Academic Settings: 1993.*

[16] To obtain a copy of this report, contact Carolyn Arena, National Science Foundation (703-306-1774 or via e-mail at carena@nsf.gov).

CHANGES IN DATA COLLECTION PROCEDURES FOR CYCLE IV[17]

The data collection procedures used in the cycle IV 1993 survey differ from those used in earlier cycles of the instrumentation survey in several ways.

1. **Minimum Instrument Purchase Price Criterion.—**To be eligible for inclusion in the three previous survey cycles, a department or facility must have had at least one research instrument with a purchase price of $10,000 or more. Similarly, only those research instruments with a purchase price of $10,000 or more were eligible for inclusion in the instrument sample in the survey. In cycle IV, the $10,000 minimum purchase price criterion was increased to $20,000 to reduce respondent burden.

   In this report, trend data were adjusted to accommodate this change in information collected. Data from the 1982–83, 1985–86, and 1988–89 surveys were standardized using the same minimum purchase price criterion of $20,000 in constant 1993 dollars, according to the GDP implicit price deflator.

2. **Survey Data Reference Periods.—**Data for the three previous survey cycles were all collected over a two-year period. Half of the included fields were collected in each year, and two different types of information were collected:

   a. Data concerning expenditures were collected with the date referring to the fiscal year that preceded the period of survey collection. Engineering, chemistry, physics/astronomy and computer science expenditure data were collected to cover the years 1982, 1985, and 1988. Expenditure data for agriculture, biology, environmental sciences, and multidisciplinary areas were collected to cover the years 1983, 1986, and 1989.

   b. Data concerning equipment adequacy, needs, and priorities were collected with the date referring to the year in which the survey was collected (i.e., 1983, 1986, and 1989 for engineering, chemistry, physics/astronomy and computer science, and 1984, 1987, and 1990 for agriculture, biology, environmental sciences and multidisciplinary fields.)

   In cycle IV, the collection method was changed and data for all fields were collected during a single year, 1994. For this report, therefore, expenditure data for all fields refer to 1993, and adequacy and needs data refer to the collection year of 1994.

3. **Change in Criterion for In-Scope Departments and Facilities.—**For the first two cycles of this survey, data were collected only for instruments with an original purchase price of $10,000 to $999,999. Beginning in cycle III, data were also collected for instruments with a purchase price of $1 million or more. To preserve the richness of trend data available since 1982–83 for instruments costing less than $1 million, the data in all trend tables in this report have been separated. This allows a display of the longitudinal data series since 1982 for the under $1 million instruments, and shows data on the over $1 million instruments beginning only in 1988–89. Where appropriate for analysis, selected other tables have also been similarly separated between the two price categories.

RESPONSE RATES, ESTIMATES, AND SAMPLING ERRORS

Response Rates.—Data were received from 54 of the 55 institutions in the sample of colleges and universities and from all 24 institutions in the sample

[17] A detailed analysis of these changes and their effects on data in the survey is also included in the same separate methodology report, *National Survey of Academic Research Instruments and Instrumentation Needs, 1993: Methodology Report.*

of medical schools. Of the 996 science and engineering departments and facilities in the sample, 796 in-scope units responded to the survey (84.0 percent). The response rate for the questionnaire items ranged from 90.0 to 100.0 percent.

Estimates.—The findings are presented as national estimates calculated using department and facility data statistically weighted to represent all research departments and facilities in agriculture, biology, environmental sciences, chemistry, computer science, physics/astronomy, and engineering. These results from the departments and facilities at the panel of 79 institutions were generalized for the 1993 survey to the universe of 318 institutions that performed a minimum of $3 million in R&D in 1991 (the latest year for which data were available at the time of calculation). This population in total accounted for more than 90 percent of the expenditures for academic R&D in science and engineering in the United States. Over the years that the survey has been conducted there has been a gradual increase in the number of institutions that perform more than $3 million in R&D. In cycle III the panel of 79 institutions represented 287 institutions that annually conducted over $3 million in R&D. In cycle II it represented 174 institutions, and in cycle I, 155 institutions.

To ensure that the reported estimates fully represent all intended institutions and department/facilities, the final weights for these estimates are the product of the institution sampling weight (for each stratum), the department sampling weight, and the nonresponse adjustment factors for both the institution and the department or facility.

The findings from the 1993 survey were compared with those from the previous three cycles. All data are presented in current dollars, as are the majority of the percentage changes included in the text. In certain analyses, it was relevant to add constant dollar comparisons of changes. In those few instances, which are specifically noted in the text, the dollar amounts were adjusted for inflation using the GDP implicit price deflator and a base year of 1987.

Sampling Errors.—The estimates presented in this report are based on samples and are subject to variability due to sampling error. Most overall estimates (not broken down by field) have sampling errors (coefficients of variation) that range from 4 to 10 percent. This implies a 95-percent confidence interval of twice that magnitude, i.e., that the true value would be found within plus or minus 8 to 20 percent of the reported estimate. Estimates for the detail data (i.e., estimates by field of science) have sampling errors two to three times larger than those for all fields combined.[18]

[18] For example, the estimated total annual expenditures for the purchase of academic scientific research instrumentation in the biological sciences were $283 million in 1993. Assuming a sampling error of 10 percent, there is a 95-percent chance that the true amount of expenditures for research instrumentation will be found within the interval of $226 million to $340 million.